

## Reducing the Sampling Frequency of Ground Water Monitoring Wells

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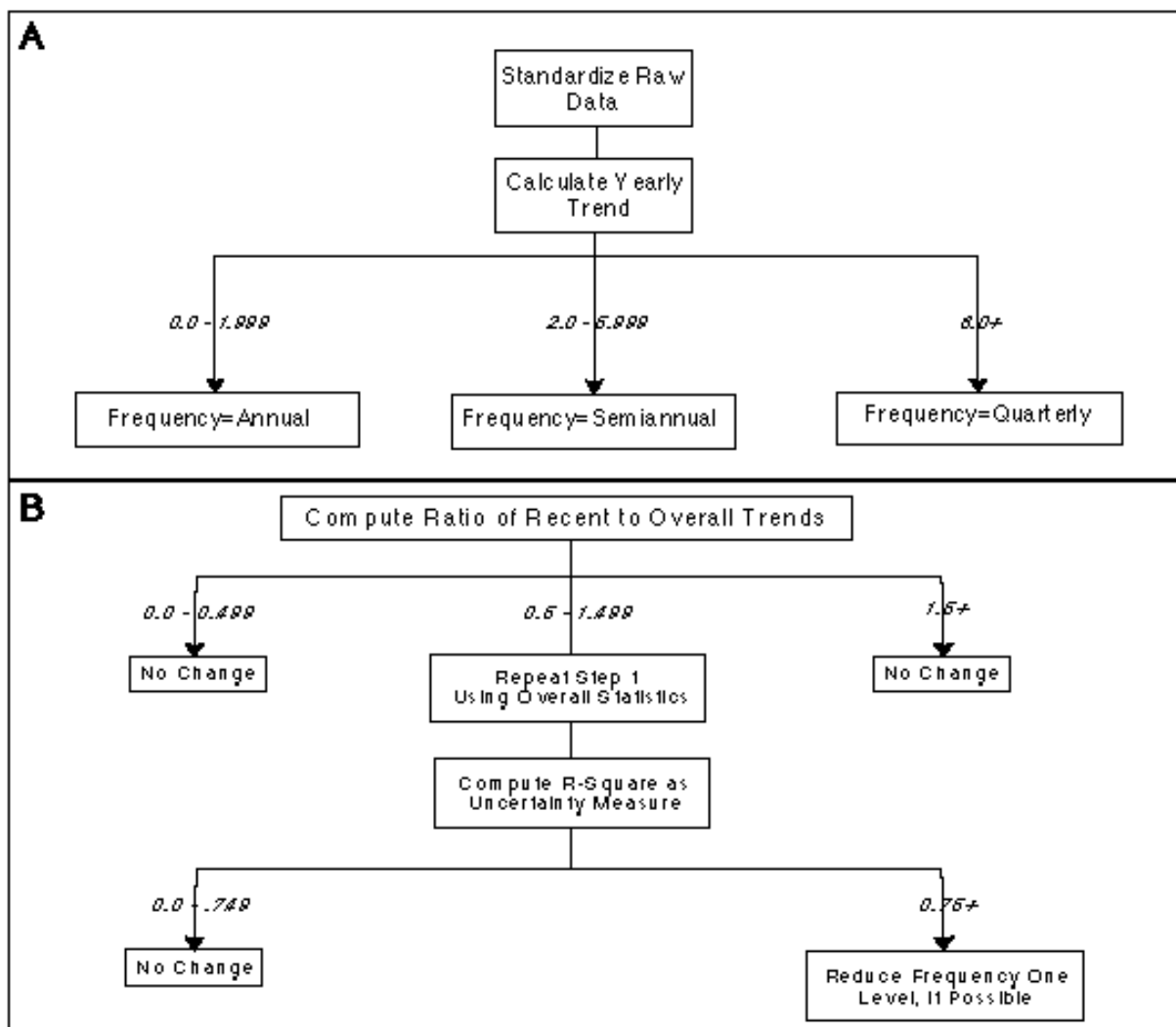
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**Introduction.** Increasing budgetary pressures are forcing organizations involved in environmental monitoring and remediation to look at every potential source of cost-savings, including those associated with sampling ground water over time. Environmental restoration personnel at the Department of Energy's Lawrence Livermore National Laboratory (LLNL) have long been concerned that their 700+ ground water monitoring wells were being sampled more often than necessary, given the arid nature and low to tens of parts per million contaminant levels present at the site. Similar questions have been raised at the Savannah River Site (SRS), where some 10,000 samples are taken from 1500+ groundwater monitoring wells at an estimated yearly cost of \$10,000,000 in laboratory fees alone. At both sites, the issue has been how to reduce sampling costs without losing information required for compliance- and remediation-related decision-making.

One approach for estimating sampling frequency is to preserve statistical independence among samples. Since ground water samples are collected over time, these samples could be correlated. When such correlations exist, the standard statistical tests required by legislation are less reliable. Statistical methods using auto-regressive techniques (1) and temporal variograms (2) have been proposed to address this problem, but these methods are technically complicated and so are not widely used by environmental professionals. As part of a joint LLNL/SRS

project, a methodology for recommending sampling schedules that blends statistical and practical knowledge has been gradually evolving. This brief report presents the methodology's basic concepts, together with early implementation results showing the estimated cost-savings.



**Figure 1. Decision-logic for recommending sampling schedules for individual compounds. A) Step 1: Set frequency based on recent trends; B) Step 2: Adjust frequency based on overall trends and predictability.**

**Methods.** The approach taken here emphasizes patterns in the contaminant data. It views the need for sampling in terms of the rate at which change is occurring in the measured concentrations of a contaminant, tempered by the degree of uncertainty associated with the calculated change. Average yearly rates of change are translated into broad scheduling categories based on common regulatory conventions: quarterly, semi-annual, and annual. In

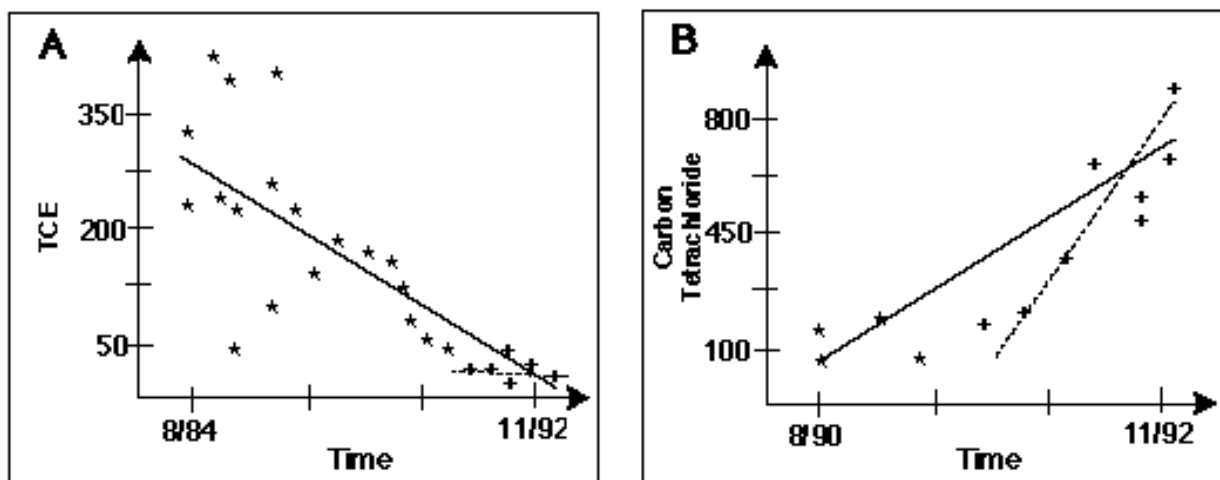
some cases, evidence of high predictability is combined with rate information to further decrease the frequency of sampling. Differing degrees of risk or hazard associated with different compounds are accommodated by standardizing raw concentrations by the drinking water standard for the compound under consideration. Decisions are initially based on data from the recent past. Data covering a well's overall history are used instead when historic and recent trends are similar. In all cases, recommendations are subject to scientific and engineering review with periodic re-evaluations.

To be considered for schedule reduction, a well must have been sampled for at least six quarters. The decision-rules are applied independently to each contaminant in the target list for a particular well. At LLNL, this list consists of 11 volatile organic compounds (VOCs) pertinent to the ground water contamination at the site. At SRS, the list consists of organic, inorganic, and radioactive compounds. The schedule assigned to the well is the most frequent schedule recommended by the algorithm for any individual contaminant.

Evaluation proceeds in two steps. In Step 1 (see Figure 1A), an initial estimate of sampling frequency is obtained by calculating average yearly trends, defined as the least-squares slope of the regression of time against concentration, based on the most recent data. Absolute values are used, since it is rate rather than direction of change that is the dominant factor. The *adjustable cut-offs* shown in Figure 1A are interpreted as follows: an Annual schedule is assigned when concentrations are changing at a yearly rate less than twice the drinking water standard for the compound; Quarterly schedules are assigned when the yearly rate of change is six times the standard or more; and Semi-annual schedules are assigned to intermediate rates.

Step 2, shown in Figure 1B, examines the ratio of the recent to overall slopes to locate instances where the schedule assignment of Step 1 should be re-evaluated. When the recent trend is clearly distinct from the overall trend (i.e. when the ratio is  $< .5$  or  $\geq 1.5$ ), the Step 1 decision is retained. An example of a pattern having a slope ratio of .003 is shown in Figure 2A. The recent flattening of the data (slope = .086) produces an annual recommendation for Trichloroethylene (TCE) even though its overall slope is -28.89. When the slopes are similar, Step 1 is repeated using all available data. In addition, since a larger sample size is usually now available, predictability information in the form of the  $R^2$  is taken into account. A high  $R^2$  leads to frequency reduction on the grounds that when change is highly predictable, there is less need for sampling. Figure 2B illustrates the case where a steep rise in Carbon Tetrachloride (overall slope = 285.836) is reduced from a quarterly to a semi-annual recommendation because the overall  $R^2 = .872$ .

**Results.** The method was applied to a 1992 benchmark VOC dataset from 296 wells at LLNL's main site. The wells had been sampled over an average of 16.3 periods spanning an average of 5.1 years. Originally, 200 wells were sampled quarterly, 90 semi-annually, and 6 annually. Eighteen wells were ineligible for reduction either because they had been sampled less than 6 times or were located close to residential areas. Of these, 11 were sampled quarterly and 7 semi-annually. Of the remaining 278, 40 were recommended for quarterly, 39 for semi-annual, and 199 for annual schedules. As a result, only 437, rather than 986, samples would be required in the coming year for all 296 wells. This translates into a savings of \$109,800/year in direct sampling costs and an estimated \$65,000/year in indirect labor and data management costs.



**Figure 2. Recent vs. overall trends in the standardized concentration of selected VOCs, originally in ppb, at individual monitoring wells (+'s identify recent samples; the dotted lines are recent trends; the y-axis corresponds to the raw concentration divided by the drinking water standard for the compound). A) The flat recent trend dictates an annual schedule for TCE despite the steep overall decline; B) The steep increase in Carbon Tetrachloride, which leads to an quarterly recommendation in Step 1, is downgraded in Step 2 to semi-annual, because of the high degree of predictability of the overall trend.**

A variant of the method was applied at SRS to data on nine contaminants from 89 F Area monitoring wells, all of which were originally sampled quarterly. A minor alteration was required to accommodate SRS's inorganic and radioactive data, which are scaled differently from organic data. The SRS method standardizes the raw concentrations for each compound by the mean for that compound within each well and applies Figure 1A cut-offs of  $< .5$  for the quarterly category and  $\geq 1.0$  for the annual category. A graph of the standardized data for each compound in each well includes a reference line showing the drinking water standard for

examination during the scientific and engineering review. The resulting recommended frequencies were 35 quarterly, 51 semi-annual, and 3 annual schedules. This reduction constitutes a lower percent change in sampling frequency than the LLNL results, but SRS routinely analyzes a larger number of compounds. Therefore, implementing the suggested schedules at SRS would still result in an approximate annual savings of \$177,000 in direct laboratory costs. Extrapolating these results to all 1500 SRS ground water wells translates into an annual savings of approximately \$1.8 million.

The strength of the current version of the method is its relative ease of application and interpretation. This, more than any other factor, contributed to the success with which an earlier version was implemented for selected wells at LLNL and approved by local EPA regulators in 1992. Work is underway to upgrade the substantive and statistical rationales for the schedule category definitions, to extend the applicability of the method to other regulatory and physical environments, and to integrate the methodology into a larger sample management scheme which includes spatial as well as temporal analyses.

## References

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